14th ICBEN 2023
18 - 22 JUNE
BELGRADE

14th ICBEN Congress on Noise as a Public Health Problem

Sensitivity of the association between aircraft noise exposure and CVD mortality

Danielle Vienneau[1,2], Benedikt Wicki[1,2], Beat Schäffer[3], Jean Marc Wunderli[3], Martin Röösli[1,2]

[1] Swiss Tropical and Public Health Institute, Allschwil, Switzerland
[2] University of Basel, Basel, Switzerland
[3] Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Acoustics/Noise Control, Dübendorf, Switzerland

Corresponding author's e-mail address: danielle.vienneau@swisstph.ch

ABSTRACT

Exposure-response relationships used to quantify burden of disease from transportation noise should reflect complex exposure and socio-demographic situations. Motivated by inconsistent findings in associations for aircraft noise and CVD mortality outcomes in Switzerland, we aimed to investigate associations specifically in proximity to airports. Prior associations in the Swiss National Cohort (including 4.1 million adults followed for up to 15 years) indicated U-shaped relationships that translated into a log-linear exposure-response of 1.003 [0.996; 1.010] for CVD and 1.040 [1.020; 1.060] for myocardial infarction (MI) mortality per 10 dB Lden aircraft noise, after adjusting for road-traffic and railway noise, air pollution and confounders. Using the same data, multi-exposure Cox proportional hazard models were derived for adults residing: a) in the four cantons around Zurich airport; and b) anywhere in Switzerland with aircraft noise exposure above 30 dB Lden. Log-linear and non-linear models were compared. Each study population included 1.2–1.3 million individuals of whom ~0.8 and 0.1 million respectively died from CVD and MI during follow up. Restricting to the broader Zurich airport area did not change the associations (CVD: 1.007 [0.996; 1.018] and MI: 1.033 [1.003; 1.063] per 10 dB Lden), and splines still indicated U-shaped relationships. Restricting to those aircraft noise exposed across Switzerland resulted in stronger associations (CVD: 1.016 [1.006; 1.028] and MI: 1.055 [1.024; 1.087] per 10 dB Lden, with an approximately log-linear relationship across the full exposure range (i.e. from above 30 dB Lden). We assume that residual confounding can influence the shape of the exposure-response relationship in administrative cohorts, in particular when including large areas with little to no exposure and large contrasts in socio-economic status.

Keywords (3-6): Aircraft Noise, Multi-exposure models, Confounding, Urban/rural environments, Exposure-response

INTRODUCTION

Aircraft noise exposure has been associated with cardiovascular risk factors (e.g. arterial stiffness, endothelial dysfunction and high blood pressure) and total or specific cardiovascular disease (CVD), such as myocardial infarction (MI), ischemic heart disease (IHD) and stroke (Correia et al. 2013, Hansell et al. 2013, Evrard et al. 2015, Dimakopoulou et al. 2017, Seidler et al. 2018, Weihofen et al. 2019, Bączalska et al. 2022). The evidence to date, however, remains sparse, with only a handful of studies (published between 2000 and 2015) evaluating the relationship between aircraft noise and CVDs in the review underpinning the WHO Environmental Noise Guidelines (van Kempen et al. 2018). In fact, only two studies (Correia et al. 2013, Hansell et al. 2013) on IHD incidence and aircraft noise were combined in the meta-analysis for a relative risk (RR) of 1.09 (95%-CI: 1.04; 1.15) per 10 dB Lden. At the time, only one cohort study – the very first from the Swiss National Cohort (SNC) by Huss et al. (2010) – was published on mortality, showing a RR of 1.04 (0.98; 1.15) per 10 dB Lden.

Since that first SNC study, we have improved the noise models and exposure assessment for Switzerland and conducted detailed analyses on the associations between transportation noise by source, including aircraft, and CVD mortality within nearly the entire adult population. In multi-exposure models, simultaneously considering each noise source (road traffic, railways, and aircraft) and adjusted for socio-demographic confounders, Héritier et al. (2017) found statistically significant increased mortality risks for MI, heart failure and ischemic stroke, and an indicative association for all CVD combined. With a longer follow up, noise exposure at two time points, and considering moving history, the subsequent study from Vienneau et al. (2022) reported similar results. The latter study also explored the shape of the exposure-response associations using splines revealing a non-linear, U-shaped, risk increase over the whole exposure range. However, above the 45 dB Lden guideline limit for aircraft noise, the risk increased in a near linear shape. This translated into a log-linear exposure-response of 1.003 (0.996; 1.010) per 10 dB aircraft noise. For MI, the spline showed the risk increase was approximately log-linear starting from the lowest exposure level of 30 dB, giving 1.040 (1.020; 1.060) per 10 dB Lden aircraft noise. So called “censoring” was used in these nation-wide Swiss studies, whereby anyone with modelled aircraft noise levels below 30 dB were set at 30 dB in order to avoid unreasonably low exposures to a specific transportation source that would not be distinguishable from background noise from diffuse sources. Thus the associations for aircraft noise included the entire population, even those not exposed to aircraft noise from a major airport.

This study was motivated by the somewhat inconsistent findings in associations for aircraft noise and CVD mortality outcomes in Switzerland. We hypothesised that the apparent protective effect in the lower range of the U-shaped relationship is due to residual confounding in the unexposed population, for which there is little possibility to correct in the nation-wide analysis. Thus, we aimed to investigate associations specifically in the populations living in proximity to airports to derive robust associations for quantifying burden of disease.

MATERIALS AND METHODS

Study population

The study population derived from the Swiss National Cohort (SNC) that links census data with births, mortality and emigration registries (Bopp et al. 2009, Spoerri et al. 2010). The SNC was approved by the Ethics Committees of the Cantons of Zurich and Bern. The study period was from 01 January 2001 to 31 December 2015, including 7.28 million observations at baseline. After exclusions, 4.1 million observations were retained. Exclusions at baseline were based on mismatches in SNC linkage (8.2% of original sample); being under 30 years of age (33.4%); missing residential coordinates or living in an institution (4.8%); missing education or socio-economic position (2.2%); or missing exposures (0.2%).

Health outcome

Definitive primary causes of death from all cardiovascular diseases (CVD) (ICD-10: I00-I99) and myocardial infarction (MI) (ICD-10: I21-I22) were investigated.

Exposure assessment

Swiss-wide exposure data, separately for aircraft, road traffic and railway noise, from the SiRENE project (Short and Long Term Effects of Transportation Noise Exposure) (Karipidis et al. 2014, Röösli et al. 2019) were available for 2001 and 2011. Aircraft noise was from the three civils airports (Zurich, Geneva and Basel), and one military airfield located in Payerne. As described in Vienneau et al. (2022), exposure was assigned at three equally-spaced time points, matched on calendar year and to account for residential history. For the middle period, the 2001 noise data were assigned to non-movers and anyone moving after 2006; the 2011 noise data were assigned to anyone moving before 2006. We used the day-evening-night (Lden) level (i.e. weighted logarithmic mean of Leq,day, Leq,evening and Leq,night with a respective penalty of 5 dB and 10 dB for evening and night) at the maximum exposed façade, based on dwelling (Héritier et al. 2017, Vienneau et al. 2019). As per our previous studies, Lden below predefined thresholds were censored at those values (i.e. set to the specified value): 35 dB for road traffic noise, and 30 dB for railway and aircraft noise. Air pollution exposure was also assigned to the residential addresses, using the 2010 annual average $PM_{2.5}$ (µg/m^3) from a European 100 × 100 m model (de Hoogh et al. 2018).

Statistical Analysis

Cox proportional hazards models, stratified by sex and with age as time scale, were used to model the association between aircraft noise and CVD or MI mortality. Participants were followed until emigration, death or end of follow-up (on 31 December 2015), which ever came first. The models included co-exposure from road traffic and railway noise, as well as $PM_{2.5}$. Models were further adjusted for 5-year period, civil status, education level, mother tongue, nationality, quintiles of local- socioeconomic position (local-SEP) (Panczak et al. 2012), area-SEP and area unemployment rate. Area-level variables were calculated as community (n=2896 in 2001, n=2585 in 2011) and cantonal averages (n=26). Where available in the census, covariates were updated at 2011 (see Vienneau et al. (2022) for details). In a sensitivity analysis, degree of urbanisation (urban, peri-urban, rural) was included as an additional adjustment.

The models were derived for adults consistently within the:

- Zurich area: those living in the four cantons Zurich, Aargau, Thurgau and Schaffhausen, thus capturing the broad area around the largest civil airport. Here the original censoring at 30 dB was used, retaining the entire eligible adult population within these cantons; and
- Swiss subset: those living anywhere in Switzerland with aircraft noise exposure > 30 dB Lden, thus dropping marginally and non-exposed individuals.

For both cohorts, individuals were dropped if the criterion (study area or Lden) was violated at any time point. Hazard ratios (HR) and 95% confidence intervals were computed, comparing log-linear (reported per 10 dB noise increment) and non-linear (natural splines with 3 degrees of freedom) models. Age and sex stratified results were also computed as per the original study.

RESULTS

Restricting the analysis to the Zurich area (four cantons around Zurich airport) and the exposed Swiss subset (those anywhere in the country with aircraft noise > 30 dB Lden) gave similar sized study populations with 1.2 and 1.3 million individuals, respectively. This accounted for ~30% of the total adult population in Switzerland in 2001. Likewise, the proportion of CVD and MI deaths in the restricted populations accounted for 28-31% of the total deaths for these outcomes in Switzerland in 2001. As expected, a higher proportion of German speaking individuals lived in the Zurich area than in the Swiss subset (86% vs. 70%). Otherwise the characteristics of the populations within each cohort were similar at baseline, though with slightly higher mean aircraft noise exposure in the exposed Swiss subset compared to the Zurich area (mean [SD]: 44.0 (7.3) vs. 39.9 [8.6] Lden aircraft noise) (Table 1).

Assuming a linear relationship, the risk increases in the Zurich area were borderline to just significant at 1.007 (0.996; 1.018) for CVD and 1.032 (1.002; 1.062) for MI per 10 dB Lden aircraft noise. The HR observed in the Swiss subset were higher, at 1.016 (1.006; 1.028) for CVD and 1.055 (1.024; 1.087) for MI. These were also stronger than in the original publication using the entire population with censoring of the marginally and non-exposed (Table 2). Plots of natural splines, combined with the AIC diagnostics comparing the model specifications, confirmed the relationships between aircraft noise and these mortality endpoints were non-linear if focusing on the population residing in the Zurich area (Figure 1, Table 3). However, the Swiss subset, that focused only on the aircraft noise exposed adults within the whole country by excluding anyone with levels ≤ 30 dB Lden, showed an approximately linear increase from this lowest exposure level. Including degree of urbanisation as an additional adjustment did not change the results. Stratified models within the exposed Swiss subset indicated the CVD mortality association for aircraft noise was modified by sex, with higher HR in the younger adults compared to older (p-value < 0.05; Table 4).

DISCUSSION

This study aimed to take a closer look into the non-linear (U-shape) pattern of association found between aircraft noise exposure and CVD and MI mortality in a previous nation-wide analysis in Switzerland. Vienneau et al. (2022) included all eligible adults, even those with little to no aircraft noise exposure. Thus, one explanation for the shape of the exposure-response could be that the protective effect in the lowest exposure range is due to residual confounding not captured by the available indicators of socio-economic status.

A similar non-linear association was found here when restricting the analysis to individuals living in the Zurich area. Despite being in relative proximity to the largest civil airport in the country, the population living in these four cantons still had a broad range of exposures. The exposure distribution also had a large spike at the beginning reflecting the individuals with aircraft noise levels equal to or below 30 dB who were assigned the default 30 dB in the censoring step (see histogram shown in the background of Figure 1). Individuals in this large group, however, can reside in very different types of communities (a continuum from urban to rural) and be highly heterogeneous in terms of socio-economic status. Further, those with truly no aircraft noise exposure are also more likely to live in very rural areas, where CVD mortality is known to be higher than in urban settings (Chammartin et al. 2016). Thus selecting the study population on relative proximity to the airport seemed to not help address potential issues of residual confounding. The censoring step in this situation may in fact contribute to confounding because it assigns a low exposure value to a largely unexposed yet higher risk population.

The alternative approach, to subset the population removing those reasonably deemed not exposed, led to a stronger and more plausible linear increased risk for CVD and MI mortality.

CONCLUSION

Administrative cohorts with no lifestyle information may be vulnerable to residual confounding. By focusing on the rather homogeneous population of aircraft exposed people, residual confounding may be minimized. Thus, in burden of disease studies on transportation noise, our recommendation is to use the exposed Swiss subset results for the aircraft noise exposure-response relationship (i.e. 1.016 (1.006; 1.028) for CVD and 1.055 (1.024; 1.087) for MI mortality per 10 dB Lden). These relationships account for co-exposure to road traffic noise, railway noise and air pollution, and further reflect the relationship in the undiluted exposed population.

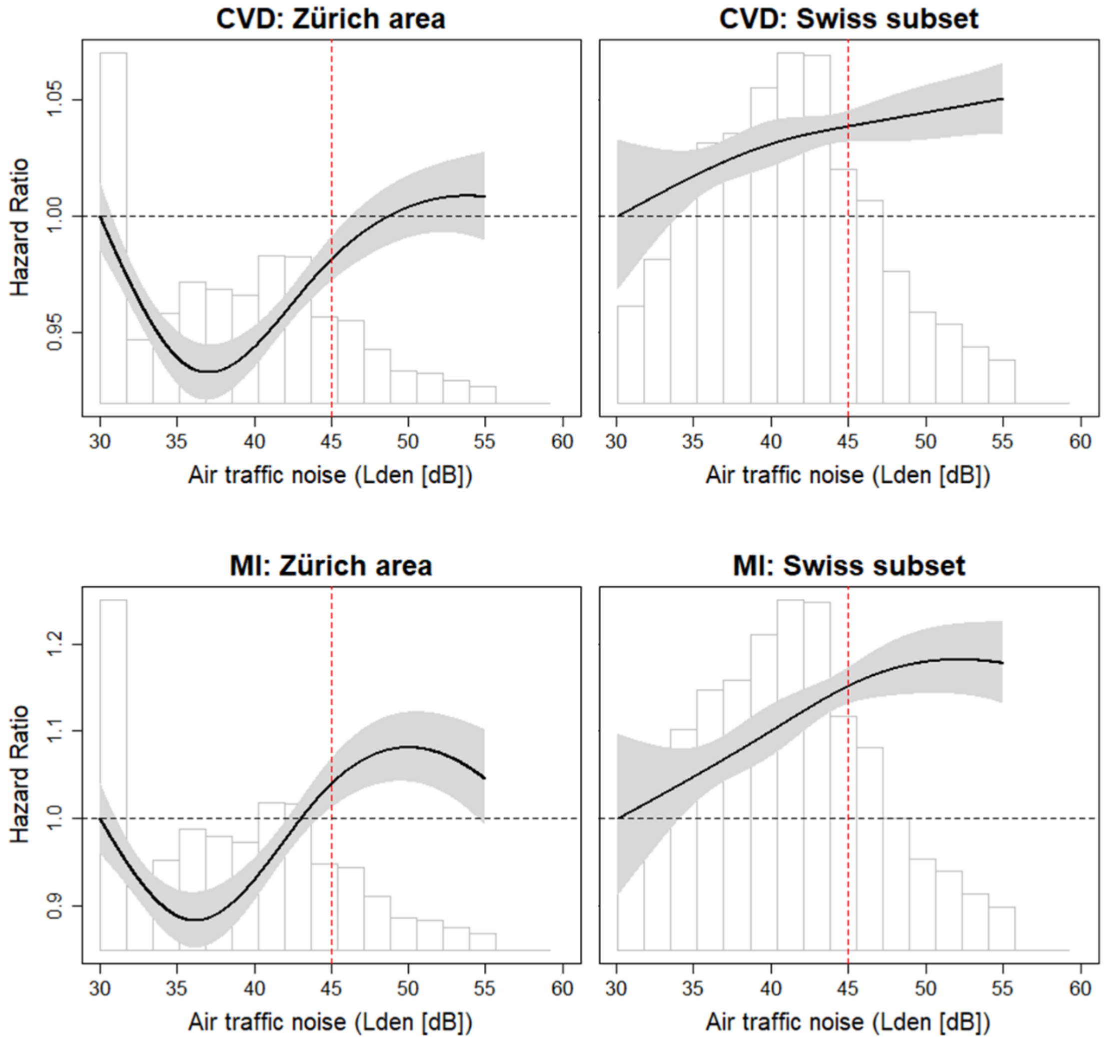

Figure 1. Natural splines for the association between aircraft noise exposure and mortality outcome overlaid on the exposure distribution, by study area

CVD = all cardiovascular diseases, MI = myocardial infarction

Fully adjusted Cox models with age as timescale: included noise exposure (aircraft noise Lden as natural spline; road traffic and railway noise Lden as linear terms); strata sex, period (i.e. 2001-2005, 2006-2010, or 2011-2015), civil status, education level, and quintiles of local-SEP; mother tongue and nationality; community and regional SEP score and unemployment; and $PM_{2.5}$ exposure

Table 1. Study characteristics at baseline

Characteristic	Zurich area (4 cantons)			Swiss subset (aircraft noise > 30 dB Lden)		
	Cohort	CVD deaths	MI deaths	Cohort	CVD deaths	MI deaths
Participants, n (%) [a]	1,201,204 (29.0)	78,028 (28.1)	10,007 (29.3)	1,295,546 (31.3)	82,840 (29.9)	10,472 (30.6)
Person-years, n	16,017,081			17,288,027		
Male, %	48.1	47.8	59.5	47.4	47.0	58.3
Age, % [b]						
30-64	77.7	10.1	20.0	76.4	9.8	19.0
65-79	17.6	30.6	37.1	18.5	30.3	36.2
80+	4.7	59.3	43.0	5.1	60.0	44.8
Mother tongue, %						
German and Rhaeto-Romansch	85.9	94.3	92.8	69.8	81.2	80.1
French	1.2	1.1	1.0	15.1	13.2	12.9
Italian	4.3	2.7	3.5	4.6	3.0	3.6
Other	8.7	1.9	2.7	10.5	2.6	3.4
Education, %						
Compulsory education or less	20.7	37.3	32.4	21.4	36.6	32.2
Upper secondary level	55.1	49.6	51.4	52.0	48.9	50.8
Tertiary level education	24.2	13.1	16.2	26.6	14.4	17.1
Marital status, % [c]						
Single	14.3	8.4	8.6	14.9	9.3	9.2
Married	69.1	46.9	55.1	67.5	45.1	52.8
Divorced	9.1	7.8	9.4	9.7	9.0	10.6
Widowed	7.5	36.9	26.9	7.8	36.7	27.5
Swiss nationality, % [c]	82.5	94.2	92.0	79.0	92.6	90.6
Local-SEP, % [d]						
national Q1	13.7	15.0	15.6	14.1	14.4	14.5
national Q2	20.6	23.5	23.7	18.0	20.6	21.4
national Q3	27.8	28.7	28.9	26.0	27.6	28.0
national Q4	37.8	32.9	31.8	41.9	37.4	36.2
Area-SEP community (%), mean (SD) [c]	66.7 (5.5)	65.0 (6.7)	65.1 (6.5)	67.3 (5.6)	65.9 (6.4)	66.0 (6.1)
Area-SEP region (%), mean (SD) [c]	0.1 (4.6)	-0.1 (5.2)	-0.1 (5.0)	0.7 (4.9)	0.5 (5.3)	0.4 (5.2)
Area unemployment community (%), mean (SD) [c]	3.5 (1.2)	3.3 (1.2)	3.3 (1.2)	4.0 (1.4)	3.7 (1.3)	3.7 (1.4)
Area unemployment region (%), mean (SD) [c]	0.0 (1.2)	0.1 (1.1)	0.1 (1.1)	0.0 (1.1)	0.1 (1.0)	0.1 (1.0)
Road Lden (dB), mean (SD) [c]	54.5 (7.7)	55.3 (7.6)	55.2 (7.5)	55.5 (7.8)	56.3 (7.6)	56.3 (7.6)
Rail Lden (dB), mean (SD) [c]	38.6 (10.8)	38.5 (10.5)	38.6 (10.7)	37.4 (10.3)	37.5 (10.1)	37.7 (10.2)
Air Lden (dB), mean (SD) [c]	39.9 (8.6)	40.0 (8.0)	40.2 (8.1)	44.0 (7.3)	43.2 (6.9)	43.4 (6.9)
$PM_{2.5}$ concentration (μg/m^3), mean (SD)	16.6 (1.3)	16.7 (1.3)	16.7 (1.3)	17.3 (1.4)	17.3 (1.4)	17.3 (1.4)

CVD = all cardiovascular diseases, MI = myocardial infarction

a. Percent: for “Cohort” is % total adult population for the Cohort, and % deaths by cause for CVD and MI deaths, based on totals of the adult population included in Vienneau et. al. (2022)
b. Age group for CD and MI deaths is according to date of death, not baseline
c. census/exposure data available at multiple time points, thus updated at 2011
d. Quartiles of local-socioeconomic position (SEP) based on national distribution, as used in Vienneau (2022)

Table 2. Hazard ratios (95% confidence intervals) for the linear association (per 10 dB Lden) between noise exposure and mortality outcome, by noise source and study area

Outcome	Area	HR (95%CI) per 10 dB Lden		
		Aircraft noise	**Road traffic noise**	**Railway noise**
CVD	Zurich area	1.007 (0.996; 1.018)	1.045 (1.034; 1.055)	1.010 (1.004; 1.017)
	Swiss subset	1.016 (1.006; 1.028)	1.054 (1.044; 1.064)	1.015 (1.008; 1.022)
	Whole country (Vienneau et al. (2022))	1.003 (0.996; 1.010)	1.029 (1.024; 1.034)	1.013 (1.010; 1.017)
MI	Zurich area	1.032 (1.002; 1.062)	1.051 (1.023; 1.079)	1.022 (1.003; 1.042)
	Swiss subset	1.055 (1.024; 1.087)	1.075 (1.047; 1.104)	1.032 (1.012; 1.052)
	Whole country (Vienneau et al. (2022))	1.040 (1.020; 1.060)	1.043 (1.029; 1.058)	1.020 (1.010; 1.030)

CVD = all cardiovascular diseases, MI = myocardial infarction
Fully adjusted Cox models with age as timescale: included noise exposure (aircraft, road traffic and railway noise Lden as linear terms); strata sex, period (i.e. 2001-2005, 2006-2010, or 2011-2015), civil status, education level, and quintiles of local-SEP; mother tongue and nationality; community and regional SEP score and unemployment; and $PM_{2.5}$ exposure

Table 3. Comparison of splines vs. linear models, by outcome and study area

Outcome	Area	Model comparison		
		Model	**AIC**	**Pr(>Chisq)**
CVD	Zurich area	linear	1003053	
		natural spline, 3df	1003011	<0.001
	Swiss subset	linear	1075984	
		natural spline, 3df	1075987	0.701
MI	Zurich area	linear	135764	
		natural spline, 3df	135737	<0.001
	Swiss subset	linear	142515	
		natural spline, 3df	142513	0.059

CVD = all cardiovascular diseases, MI = myocardial infarction
Fully adjusted Cox models with age as timescale: included noise exposure (aircraft noise Lden as linear term or natural spline as indicated; road traffic and railway noise Lden as linear terms); strata sex, period (i.e. 2001-2005, 2006-2010, or 2011-2015), civil status, education level, and quintiles of local-SEP; mother tongue and nationality; community and regional SEP score and unemployment; and $PM_{2.5}$ exposure

Table 4. Effect modification by age or sex. Hazard ratios (95% confidence intervals) for the linear association (per 10 dB Lden) between noise exposure and mortality outcome, by noise source for the **Swiss subset**

Outcome	Source	Male	Female	p-interaction	30-60	65-79	80+	p-trend
CVD	Air	1.012 (0.997; 1.028)	1.019 (1.004; 1.035)	0.538	1.053 (1.019; 1.088)	1.020 (1.001; 1.040)	1.006 (0.992; 1.020)	0.039
	Road	1.079 (1.064; 1.094)	1.032 (1.019; 1.046)	<0.001	1.128 (1.095; 1.162)	1.086 (1.068; 1.105)	1.026 (1.013; 1.038)	<0.001
	Rail	1.019 (1.009; 1.030)	1.010 (1.001; 1.020)	0.192	1.052 (1.029; 1.074)	1.018 (1.006; 1.031)	1.005 (0.996; 1.014)	0.001
MI	Air	1.050 (1.010; 1.091)	1.062 (1.013; 1.114)	0.703	1.069 (1.000; 1.143)	1.063 (1.012; 1.117)	1.045 (0.998; 1.094)	0.814
	Road	1.103 (1.065; 1.142)	1.035 (0.994; 1.079)	0.022	1.135 (1.069; 1.205)	1.102 (1.054; 1.152)	1.028 (0.988; 1.069)	0.010
	Rail	1.044 (1.018; 1.070)	1.017 (0.987; 1.048)	0.195	1.055 (1.010; 1.101)	1.028 (0.996; 1.061)	1.026 (0.997; 1.056)	0.551

CVD = all cardiovascular diseases, MI = myocardial infarction
Fully adjusted Cox models with age as timescale: included noise exposure (aircraft noise, road traffic and railway noise Lden as linear terms); strata sex*, period (i.e. 2001-2005, 2006-2010, or 2011-2015), civil status, education level, and quintiles of local-SEP; mother tongue and nationality; community and regional SEP score and unemployment; and $PM_{2.5}$ exposure. *only in models including both sexes

Acknowledgements

This work was supported by the Swiss National Science Foundation (Tranquil2 project, grant no. 324730B_201272).

We also thank the Swiss Federal Statistical Office for providing mortality and census data and for the support which made the Swiss National Cohort and this study possible. We also acknowledge the members of the Swiss National Cohort Study Group: Matthias Egger (Chairman of the Executive Board), Adrian Spoerri and Marcel Zwahlen (all Bern), Milo Puhan (Chairman of the Scientific Board), Matthias Bopp (both Zurich), Martin Röösli (Basel), Murielle Bochud (Lausanne) and Michel Oris (Geneva).

REFERENCES

Bączalska, J., W. Wojciechowska, M. Rojek, O. Hahad, A. Daiber, T. Münzel and M. Rajzer (2022). "Cardiovascular consequences of aircraft noise exposure." Front Public Health **10**: 1058423.
Bopp, M., A. Spoerri, M. Zwahlen, F. Gutzwiller, F. Paccaud, C. Braun-Fahrländer, A. Rougemont and M. Egger (2009). "Cohort Profile: The Swiss National Cohort—a longitudinal study of 6.8 million people." International Journal of Epidemiology **38**(2): 379-384.
Chammartin, F., N. Probst-Hensch, J. Utzinger and P. Vounatsou (2016). "Mortality atlas of the main causes of death in Switzerland, 2008-2012." Swiss Med Wkly **146**: w14280.
Correia, A. W., J. L. Peters, J. I. Levy, S. Melly and F. Dominici (2013). "Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: multi-airport retrospective study." British Medical Journal **347**: f5561.
de Hoogh, K., J. Chen, J. Gulliver, B. Hoffmann, O. Hertel, M. Ketzel, M. Bauwelinck, A. van Donkelaar, U. A. Hvidtfeldt, K. Katsouyanni, J. Klompmaker, R. V. Martin, E. Samoli, P. E. Schwartz, M. Stafoggia, T. Bellander, M. Strak, K. Wolf, D. Vienneau, B. Brunekreef and G. Hoek (2018). "Spatial PM2.5, NO2, O3 and BC models for Western Europe – Evaluation of spatiotemporal stability." Environment International **120**: 81-92.
Dimakopoulou, K., K. Koutentakis, I. Papageorgiou, M.-I. Kasdagli, A. S. Haralabidis, P. Sourtzi, E. Samoli, D. Houthuijs, W. Swart, A. L. Hansell and K. Katsouyanni (2017). "Is aircraft noise exposure associated with cardiovascular disease and hypertension? Results from a cohort study in Athens, Greece." Occupational and environmental medicine **74**(11): 830-837.
Evrard, A. S., L. Bouaoun, P. Champelovier, J. Lambert and B. Laumon (2015). "Does exposure to aircraft noise increase the mortality from cardiovascular disease in the population living in the vicinity of airports? Results of an ecological study in France." Noise Health **17**(78): 328-336.
Hansell, A. L., M. Blangiardo, L. Fortunato, S. Floud, K. de Hoogh, D. Fecht, R. E. Ghosh, H. E. Laszlo, C. Pearson, L. Beale, S. Beevers, J. Gulliver, N. Best, S. Richardson and P. Elliott (2013). "Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study." BMJ **347**: f5432.
Héritier, H., D. Vienneau, M. Foraster, I. C. Eze, E. Schaffner, L. Thiesse, F. Rudzik, M. Habermacher, M. Kopfli, R. Pieren, M. Brink, C. Cajochen, J. M. Wunderli, N. Probst-Hensch and M. Roosli (2017). "Transportation noise exposure and cardiovascular mortality: a nationwide cohort study from Switzerland." Eur J Epidemiol **32**(4): 307-315.
Huss, A., A. Spoerri, M. Egger, M. Röösli and for the Swiss National Cohort (2010). "Aircraft noise, air pollution, and mortality from myocardial infarction." Epidemiology **21**(6): 829-836.
Karipidis, I., D. Vienneau, M. Habermacher, M. Köpfli, M. Brink, N. Probst-Hensch, M. Röösli and W. Jean-Marc (2014). "Reconstruction of historical noise exposure data for environmental epidemiology in Switzerland within the SiRENE project." Noise Mapping(1): 3-14.
Panczak, R., B. Galobardes, M. Voorpostel, A. Spoerri, M. Zwahlen and M. Egger (2012). "A Swiss neighbourhood index of socioeconomic position: development and association with

mortality." J Epidemiol Comm Health **66**(12): 1129–1136.
Röösli, M., J.-M. Wunderli, M. Brink, C. Cajochen and N. Probst-Hensch (2019). "Bruit du trafic, mortalité cardiovasculaire, diabète, troubles du sommeil et nuisance - L'étude SiRENE." Forum Med Suisse **19(0506)**: 77-82.
Seidler, A. L., J. Hegewald, M. Schubert, V. M. Weihofen, M. Wagner, P. Dröge, E. Swart, H. Zeeb and A. Seidler (2018). "The effect of aircraft, road, and railway traffic noise on stroke - results of a case-control study based on secondary data." Noise Health **20**(95): 152-161.
Spoerri, A., M. Zwahlen, M. Egger and M. Bopp (2010). "The Swiss National Cohort: a unique database for national and international researchers." Int J Public Health **55**(4): 239-242.
van Kempen, E., M. Casas, G. Pershagen and M. Foraster (2018). "WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cardiovascular and Metabolic Effects: A Summary." Int J Environ Res Public Health **15**(2).
Vienneau, D., H. Héritier, M. Foraster, I. C. Eze, E. Schaffner, L. Thiesse, F. Rudzik, M. Habermacher, M. Köpfli, R. Pieren, M. Brink, C. Cajochen, J. M. Wunderli, N. Probst-Hensch and M. Röösli (2019). "Façades, floors and maps – Influence of exposure measurement error on the association between transportation noise and myocardial infarction." Environment International **123**: 399-406.
Vienneau, D., A. Saucy, B. Schäffer, B. Flückiger, L. Tangermann, M. Stafoggia, J. M. Wunderli and M. Röösli (2022). "Transportation noise exposure and cardiovascular mortality: 15-years of follow-up in a nationwide prospective cohort in Switzerland." Environment International **158**: 106974.
Weihofen, V. M., J. Hegewald, U. Euler, P. Schlattmann, H. Zeeb and A. Seidler (2019). "Aircraft Noise and the Risk of Stroke: A Systematic Review and Meta-analysis." Dtsch Arztebl Int **116**(14): 237-244.